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Viewpoint

# The Evolution From Surgery to Percutaneous Mitral Valve Interventions

## The Role of the Edge-to-Edge Technique

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**The edge-to-edge technique is a versatile procedure for mitral valve repair. Its technical simplicity has been the prerequisite for the development of a number of transcatheter technologies to perform percutaneous mitral valve repair. The evolution from a standard open heart surgical to percutaneous procedure involved the application of the technique in minimally invasive robotic surgery and direct access (transatrial) off-pump suture-based repair and finally in the fully percutaneous approach with either suture-based or device (clip)-based approach. The MitraClip (Abbott Vascular, Menlo Park, California) is currently available for clinical use in Europe, and it is mainly applied to treat high-risk patients with functional mitral regurgitation. A critical review of the surgical as well as the early percutaneous repair data is necessary to elucidate the clinical role and the potential for future developments of the edge-to-edge repair in the treatment of mitral regurgitation. (J Am Coll Cardiol 2011;58: 2174–82) © 2011 by the American College of Cardiology Foundation**

The edge-to-edge is a surgical technique developed by Alfieri (1–3) in the early 1990s to treat mitral regurgitation (MR). The technique is technically simple and used to treat both organic and functional MR. The surgical technique consists of the suture of the free edge of the leaflets at the site of regurgitation, creating a valve with 2 orifices when the regurgitation originates from the middle scallops. For this reason it has also been named "double orifice" technique (Fig. 1).

As opposed to conventional techniques, the edge-to-edge repair is not directly addressing the anatomical lesion: MR is corrected by obliteration of the regurgitant orifice at the leaflet level. This innovative concept implies that the same technique can be applied to different anatomical and functional conditions.

The value of the technique has been long debated in the surgical arena, initially with several detractors and few adopters, mainly because of the perceived non-physiological consequences. Yet, the technique has been demonstrated safe, effective, and durable, and many surgeons have progressively adopted it.

Its technical simplicity and versatility has been the foundation for the development of transcatheter technologies, including the MitraClip (Abbott Vascular, Inc., Menlo Park, California). Herein we review the evidence on the surgical as well as the transcatheter techniques outcomes to better understand the clinical role of percutaneous mitral valve interventions.

## The Origins

The edge-to-edge technique was first performed in 1991 to successfully treat a patient with anterior leaflet prolapse. At that time, anterior leaflet repair was considered challenging, and most patients would undergo replacement. The day before, Alfieri had operated on another patient for correction of atrial septal defect who had, as a concomitant asymptomatic condition, a perfectly competent congenital double-orifice valve. Initially the technique was applied only selectively, in patients with complex anatomies, and usually without a concomitant annuloplasty, because of the fear of stenosis. Because mid-term results were suggesting safety, effectiveness, and durability, gradually the edge-to-edge technique became routine at our institution. At the peak of the adoption rate (between 1998 and 2005), it was used in one-third of patients undergoing mitral valve repair. The most common indications were anterior/bileaflet disease and functional MR. More recently, the rate of edge-to-edge repair at our institution decreased in favor of more anatomical corrections, although it remains used in approximately 15% of patients with complex anatomy or requiring an expedited procedure.

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## Doubts and Answers

Numerous experimental models addressed the hemodynamic and structural effects of the technique (4,5).

The first concern was the risk of creating stenosis, although this was rarely seen in clinical practice. A computational model (Fig. 2) of the double orifice mitral valve with orifices of same or different size suggested hemodynamics are not affected by the double orifice configuration, even in case of asymmetric position of the double orifice suture (6).

Later, clinical studies (7) showed that the procedure does not impair valve diastolic function either at rest or under exercise. Agricola et al. (8) reported normal response to exercise echocardiography: at peak stress, heart rate, systolic blood pressure, and stroke volume were significantly increased, maintaining a physiological behavior of the valve. Valve reserve was preserved: planimetric area increased significantly ($3.2 \pm 0.6$ cm$^2$ vs. $4.3 \pm 0.7$ cm$^2$, $p < 0.00001$) during exercise. Subsequently, Hori et al. (7) observed that exercise response of patients treated with edge-to-edge repair is equal to those treated with conventional repairs.

Limited durability and the risk of suture dehiscence were initially perceived as a critical issue, although rarely seen in clinical practice. Nielsen et al. (4) analyzed the tension forces acting on the edge-to-edge suture in an ovine model of acute ischemic MR. They observed cyclic changes in the forces, proportional to the septolateral annular dimension. These results were confirmed by Votta et al. (5) with a 3-dimensional (3D) computational model. The surgical edge-to-edge has been usually associated with annuloplasty, on the basis of these findings.

**Abbreviations and Acronyms**

**3D** = 3-dimensional
**MR** = mitral regurgitation
**TEE** = transesophageal echocardiography

## Surgical Technique: What to Do and What Should Not Be Done

The edge-to-edge technique has evolved in a standardized approach, on the basis of clinical experience and laboratory findings (5,6), with improvement of efficacy and durability (2). To be effective, the edge-to-edge suture should incorporate the diseased segment(s) completely. Although a long suture reduces structural stress on the leaflets (5), it determines a larger reduction of effective orifice area. A middle suture creates a 40% to 50% reduction of valve area from baseline. This is usually not an issue in degenerative disease,

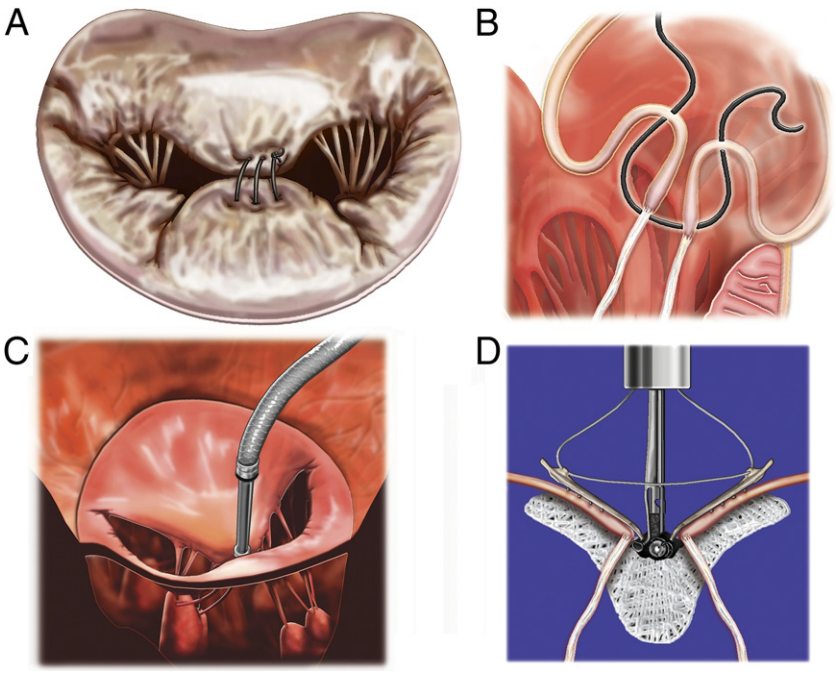


**Figure 1** Surgical Edge-to-Edge Technique Versus MitraClip

**(A)** The surgical technique involves a continuous suture of the free edge of the leaflets at the site of the regurgitation. In case the lesion is in the A2-P2 area, a double orifice valve is created. **(B)** The sutures engage the free edge of the facing leaflets, suture bite depth depends on the amount of redundant tissue (larger in case of degenerative disease, and minimal in case of functional mitral regurgitation). **(C)** The MitraClip (Abbott Vascular, Menlo Park, California) is implanted in the A2-P2 region, similarly to the surgical technique. The drawing illustrates the clip partially open, to demonstrate tissue penetration into the clip. Once proper leaflet grasping is confirmed, the clip is closed to enhance coaptation. **(D)** The free edges of the leaflets are engaged between the clip arms and the grippers. The clip is closed with leaflet facing. Compared with surgery where tissue is imbricated into the suture with no evidence of planar surface of coaptation, the MitraClip is designed to induce a linear apposition of leaflets to enhance coaptation. Figure illustration by Craig Skaggs.

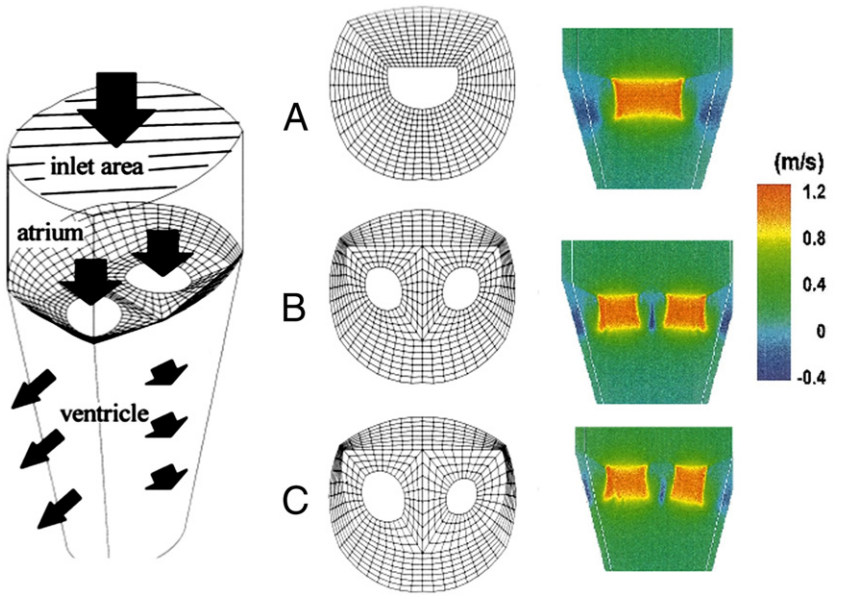


**Figure 2** **Mathematical Model of the Hemodynamics After the Double Orifice Edge-to-Edge Repair**

The mathematical model has been developed to simulate the diastolic flow patterns of 3 mitral valves of the same area but with 3 anatomical configurations: a single orifice **(A)**, a double orifice with equal orifice sizes **(B)**, and 1 with uneven orifice sizes **(C)**. Flow velocity patterns show similar velocities in single and in double orifice valves, suggesting that the hemodynamics of the mitral valve are not influenced by the geometrical conformation of the orifice.

but it might cause mitral stenosis in patients with valve area smaller than 4 $cm^2$. An eccentric position of the edge-to-edge suture determines smaller reduction of valve area. Additionally, post-repair effective orifice area depends on leaflet mobility and pliability; therefore the technique is less applicable and associated with shorter durability in case of rheumatic disease (1). Suture should be symmetric to avoid distortions and increased stress. Originally, the edge-to-edge sutures were reinforced with pledgets; with increasing experience, continuous sutures have been used more often.

## Clinical Outcomes in Diverse Clinical Settings

In 1998, we reported the first relatively large series of patients treated with the edge-to-edge technique (3), including 121 patients (of 432 valve repairs) operated between 1991 and 1997. Most patients had degenerative disease with anterior or bileaflet disease. A double orifice repair was done in 60% of patients. Annuloplasty was performed in only 7% of patients (small mitral annulus in 6 patients, and rheumatic disease in 2 patients). Excluding annuloplasty, the edge-to-edge was used as an isolated technique in 73% of cases, even for multiple lesions. Hospital mortality was 1.6%, and 6-year actuarial survival was 92 ± 3.1%. Freedom from reoperation was 95 ± 4.8% overall and 98 ± 1.6% for patients with isolated anterior leaflet prolapse; no patient with posterior prolapse required reintervention. Echocardiographic follow-up showed a mean degree of MR of 0.4 ± 0.83 with 91% of patients having no or trivial MR. Mean valve area was 3.0 ± 1 $cm^2$, with no patients with mitral stenosis.

Subsequently, we published a homogeneous series of 82 patients (2) treated with edge-to-edge technique as a standardized approach to correct Barlow's disease with bileaflet prolapse (condition considered a contraindication for repair). Annuloplasty was performed in 75 patients.

Today anterior/bileaflet prolapse is effectively treated with neochordae implantation; nevertheless the edge-to-edge technique has been the first method to neutralize anterior leaflet lesions as risk factor for repair failure and shorter durability (9,10). De Bonis et al. (11) compared the long-term outcomes of 122 patients with anterior prolapse treated by edge-to-edge repair with 605 patients with posterior prolapse treated with resection. All patients had concomitant annuloplasty. Hospital mortality was 0% and 0.3% in the edge-to-edge and resection groups, respectively. At 10 years, overall survival was 91 ± 4% for edge-to-edge and 93 ± 2% for resection group ($p = 0.18$). Freedom from reoperation was 96 ± 2% and 96 ± 1% ($p = 0.37$) in the edge-to-edge and resection groups, respectively. Echocardiographic follow-up showed comparable freedom from recurrent MR for the 2 techniques.

Other groups reported their experience with the edge-to-edge technique in the setting of degenerative disease, confirming the aforementioned results (12,13), including when used with minimally invasive or robotic approach (14,15).

The Alfieri technique has been effectively used to treat functional MR, usually as an adjunct to undersized annuloplasty (3,13,16). We selectively applied it with an echo-based approach in patients with coaptation depth longer than 10 mm. In a retrospective series (16) of 77 patients with functional MR treated with annuloplasty alone (n = 23) or in association with edge-to-edge (n = 54), freedom from repair failure at 1.5 years was 95 ± 3% and 77 ± 12%, respectively (p = 0.04), and the multivariable analysis identified the absence of the edge-to-edge suture as an independent factor for repair failure.

The edge-to-edge repair has been successfully used in other settings: to treat failed repair as a bailout procedure, to correct systolic anterior motion in the context of hypertrophic cardiomyopathy and to treat secondary MR in patients undergoing ventricular remodeling or aortic valve surgery. We initially applied it in rheumatic disease patients, but we observed poor long-term outcomes and greater risk of high transvalvular gradients (1).

## Edge-to-Edge Without Annuloplasty

Annuloplasty is routinely performed in surgical mitral repair to improve early and long-term results (9). The same concept applies to the edge-to-edge technique: in the overall population, the absence of the annuloplasty is associated with shorter durability (1). Although initially we often omitted annuloplasty in the fear of inducing stenosis, subsequently a ring has been routinely implanted in most patients. Alfieri et al. (1) reported shorter durability in patients treated without annuloplasty. However, these patients usually had conditions preventing ring implantation that could directly influence durability such as annular calcification, endocarditic or rheumatic disease, setting of minimally invasive and robotic interventions, or a previously failed attempt of repair. The outcomes of 81 patients treated by edge-to-edge repair without annuloplasty showed overall 85 ± 7% survival and 89 ± 3.9% freedom from reoperation at 4 years. Annular calcification was associated with higher reoperation rate (77 ± 22% vs. 95 ± 4.6% in the calcified vs. noncalcified annulus, p = 0.03). Late failure was predicted by early residual MR assessed either by saline testing or intraoperative transesophageal echocardiography (TEE) (17). Therefore, in absence of annular calcification or complex anatomy (rheumatic disease, endocarditis, rescue repair, and the like), mid-term durability of isolated edge-to-edge is acceptable, as confirmed by a sub-analysis of the long-term outcomes of selected patients with ideal anatomy treated without annuloplasty (18). Although these findings were the clinical proof of concept for the isolated percutaneous treatment, we strongly believe that the addition of a percutaneous annuloplasty would improve clinical results and expand the indications for transcatheter mitral valve edge-to-edge.

## The Transition From a Surgical Procedure to the Transcatheter Approach

We firstly predicted the feasibility of a transcatheter/percutaneous approach adopting the edge-to-edge concept (3). Morales et al. (19) first described a device for beating-heart edge-to-edge repair with a tissue grasper. Alfieri et al. (20) reported the early animal experience with a suture-based device for double orifice repair with a beating-heart, direct transatrial approach. The device had suction ports at its distal tip to grasp the leaflets under echo-guidance and subsequently approximate them by deploying 2 single sutures. Then the sutures were tied with a knot pusher to get the double orifice. In parallel, a percutaneous catheter with similar characteristics had been developed (21): Mobius (Edwards Lifesciences, Irvine, California). The procedure involved a transeptal approach and the sequential grasping of leaflets under echo-guidance. After needle penetration of the leaflets, the suture was exteriorized and fastened with a Nitinol suture clip to create the double orifice. The device proved safe and effective in the animal experience. Because suture-based approximation was closely replicating the surgical predicate therapy, the device could be considered a "transcatheter needle-holder." After the Milano II multicenter safety and feasibility trial, the program was discontinued for evidence of limited efficacy and durability. Webb et al. (22) reported the outcomes of 15 patients treated in 4 international sites: acute reduction of MR was obtained in 9 of 15 patients, but improvement in MR appeared durable in only 6 patients at 30 days. The main limitation for the success of the Mobius was lack of adequate image guidance (due to the poor echogenicity of the device). The limited durability was related to insufficient tissue penetration of the suture and to asymmetric deployment of sutures.

The first animal report of the MitraClip is by St. Goar et al. (23), who reported acute procedural success in 12 of 14 animals. Interestingly, in 2 animals the clip detached acutely from the anterior leaflet due to incomplete grasp. Today, before final release, a careful analysis of leaflet incorporation into the clip is carried out to prevent clip detachment. Fann et al. (24) described the healing process in chronic animals implanted with the MitraClip, showing tissue incorporation of the device similar to that observed after surgical suture approximation (25).

## The Mitraclip: Clinical Experience From First-in-Man to Commercial Use

The Mitraclip has been used in humans with success, due to the very promising animal experience. The main drivers for success of the therapy have been the precise and stable delivery system, the solid and reliable tissue approximation, the good visualization of the device, and its repositionability and retrievability. Although the MitraClip has been designed to replicate the surgical suture-based approach, tissue

approximation is more efficient with better surface of coaptation, compared with suture (Fig. 1). The main strength of the Mitraclip is feasibility of the procedure under beating heart conditions, guided by the regurgitant jet position. This is particularly valuable for functional MR. The main weakness is the limited applicability, according to strict anatomical features, whereas surgical edge-to-edge can be applied more widely, mainly because of annuloplasty and combination with additional techniques.

The MitraClip delivery system includes a tri-axial catheter system composed of a steerable guide catheter and a clip delivery system catheter holding the implantable clip. The guide catheter size is 24-F at the groin and 22-F at the atrial septum and allows precise and stable maneuvers into the left side of the heart. The clip is a cobalt/chromium implant including 2 arms and 2 "grippers" independently securing the leaflets after grasping. The clip arms and grippers are covered with polyester to enhance tissue healing.

The MitraClip is implanted through a sequence of standardized steps that have been described by the EVEREST (Endovascular Valve Edge-to-Edge REpair Study) investigators (26). The implant is performed under general anesthesia and guided by TEE and fluoroscopy. Transeptal puncture is performed in the mid-superior and posterior aspect of the fossa ovalis, to achieve proper alignment of the system. The clip delivery system is advanced into the left atrium, perpendicular to the annular plane (Fig. 3A). The clip is positioned inside the MR jet, above the regurgitant orifice, with Doppler TEE as guidance. The clip arms are opened to 180° and oriented perpendicularly to the line of

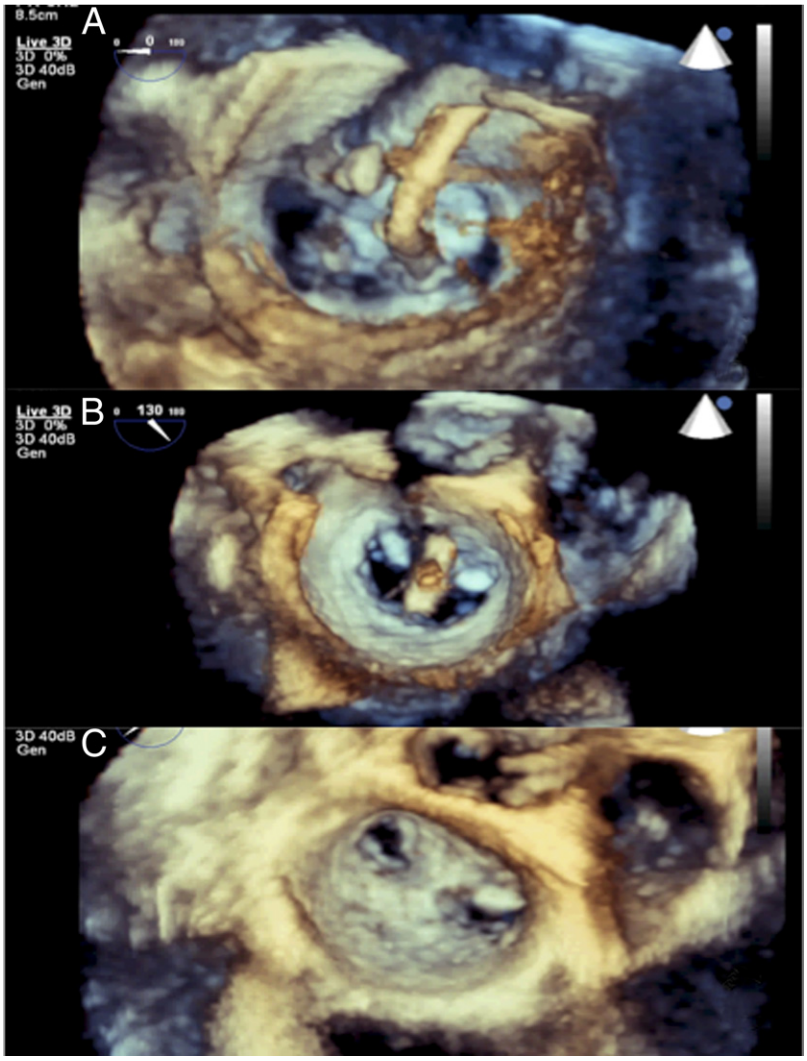


**Figure 3** 3D Echocardiography to Guide the MitraClip Implant Procedure

**(A)** The MitraClip delivery system is positioned in the left atrium across the septum and directed toward the mitral valve, along the long axis of the heart and perpendicular to the annular plane. **(B)** The clip arms are opened and oriented perpendicularly to the line of coaptation. **(C)** The clip has been implanted, and a double orifice valve is obtained. 3D = 3-dimensional.

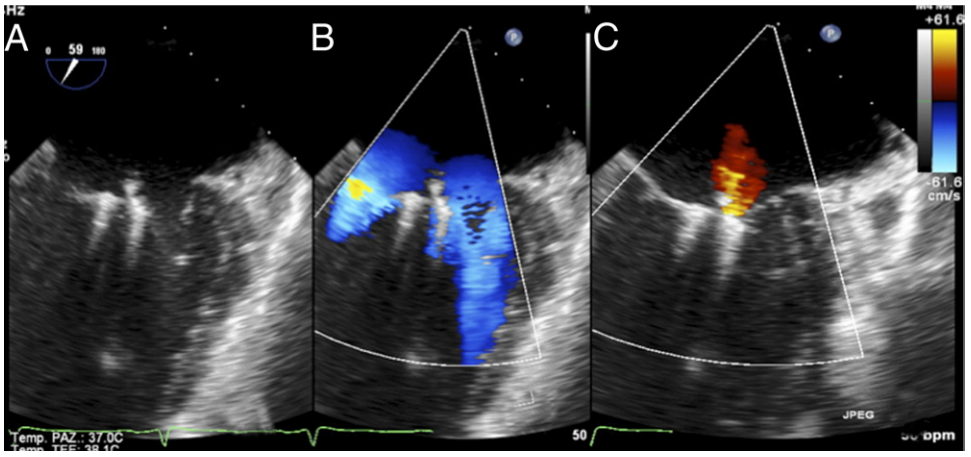


**Figure 4** **Hemodynamic Outcome of a Double MitraClip Implant**

**(A)** Bidimensional echocardiography at 60° to show the intercommissural view. Two clips are implanted in the middle of the valve. **(B)** The diastolic flow shows no turbulence. **(C)** A residual minimal jet is found laterally to the second implanted clip.

coaptation (Fig. 3B). Symmetric implant is fundamental for effective and durable repair, similarly to the surgical technique. The overall procedure today is more expeditious with the use of 3D TEE (27), owing to both the intuitive display of the mitral anatomy and the ability to image the device and the target lesions in simultaneous perpendicular planes (x-plane). The clip is advanced into the left ventricle, below the line of coaptation, and it is partially closed to get a V shape. Leaflets are grasped by gentle retraction of the clip toward the left atrium. To secure the leaflets into the device, the grippers are dropped and the clip is closed to approximately 60° to allow assessment of leaflet insertion. This step is reversible and resembles the surgical procedure, when a temporary central suture is used to assess symmetry and efficacy of the position (2). When the clip is closed, the final effect on MR reduction is evaluated, and the clip is released (Fig. 3C). If the result is unsatisfactory, the clip can be opened, inverted to release the leaflets and repositioned. Alternatively a second clip can be used to improve the result of the first one (Fig. 4). Rarely has a third clip been used in clinical practice. At the end of the procedure, the guide catheter is removed and the femoral access is closed. The first-in-man procedure was performed in 2003, in a patient with anterior leaflet prolapse. Two years after the procedure, the patient showed mild residual MR and evidence of positive reverse remodeling (28). After the first-in-man experience, the EVEREST I feasibility study was completed in 2006, enrolling 55 patients. Feldman et al. (26) reported the pooled data from EVEREST I and 52 "roll-in" EVEREST II patients (treated before randomization as part of the training) demonstrating the safety of the procedure as well as efficacy in selected patients. In the EVEREST II trial (29), a total of 279 patients at 37 sites were randomized from September 2005 through November 2008 in a 2:1 ratio to undergo either percutaneous repair (n = 184) or mitral-valve surgery (n = 95). The inclusion and exclusion criteria included restrictive clinical and anatomical variables (Table 1). The primary efficacy composite endpoint was freedom from death, from surgery for valve dysfunction, and from MR ≥three-fourths at 12 months. The primary safety endpoint was the rate of major adverse events at 30 days, defined as the composite of death, myocardial infarction, reoperation for failed mitral repair, nonelective cardiovascular surgery for adverse events, stroke, renal failure, deep wound infection, prolonged mechanical ventilation, gastrointestinal complication requiring surgery, new-onset permanent atrial fibrillation, septicemia, and transfusion of 2 units or more of blood.

In the intention-to-treat analysis, the rates of death and of recurrence of MR >3+ at 12 months were similar in the 2 groups, whereas the rate of surgery for mitral valve dysfunction was 20% in the Mitraclip arm, as compared with 2.2% in the surgery arm. Overall, the rates of the

**Table 1** **Anatomical Selection Criteria for the MitraClip Device**

| |
|---|
| Recommended anatomical criteria (from the EVEREST trial) |
| MR originates from the A2-P2 area |
| Coaptation length >2 mm |
| Coaptation depth <11 mm |
| Flail gap <10 mm |
| Flail width <15 mm |
| Mitral valve orifice area >4 $cm^2$ |
| Additional criteria for caution |
| Short posterior leaflet (<8 mm) |
| Restricted posterior leaflet prolapse/flail width >15 mm |
| Calcification in the grasping area |
| Cleft or subcommissures in the area of the jet |

MitraClip (Abbott Vascular, Menlo Park, California).
EVEREST = Endovascular Valve Edge-to-Edge REpair Study; MR = mitral regurgitation.

primary efficacy endpoint were 55% and 73% in the percutaneous and surgery group, respectively ($p = 0.007$). In the intention-to-treat analysis, the rates of major adverse events at 30 days after the procedure were 15% in the MitraClip arm and 48% in the surgery arm, with a 1-sided upper limit of the 97.5% confidence interval of −21% (lower than the −2% margin of increased safety; $p < 0.001$). There was improvement in the severity of MR in the 2 groups, but it was greater after surgery ($p < 0.001$). In the MitraClip group, 23% had residual MR ≥2. However, the majority of patients who had improved MR after the procedure had a sustained improvement at 24 months of follow-up, and 78% of patients remained free from mitral valve surgery. Despite the difference in the reduction in MR degree, both groups observed a similar degree of reverse left ventricular remodeling and improvement of symptoms. The mismatch between MR reduction and clinical improvement raises the issue of the reliability of current methods of MR quantification. Most quantitative or qualitative methods have been designed to assess the degree of regurgitation in the setting of a single regurgitant orifice, whereas after the Mitraclip often 2 or more jets are encountered. Recently, it has been shown that the presence of 2 regurgitant orifices results in overestimation of the jet color Doppler area (30). Furthermore, the clinical meaning of a residual moderate MR (grade 2/4) is still debated, because this outcome is classically not acceptable after surgical repair and is associated with accelerated repair failure. The 2-year data suggest that recurrent MR develops in the first 6 months after the procedure; thereafter, the hemodynamic result of the MitraClip remains stable. Patients with failed repair had undergone surgery with preserved repair option in the majority of cases, although this issue is still debated (31). A post hoc analysis (non–pre-specified and purely exploratory) suggests that surgery was nonsuperior to the percutaneous treatment in patients older than 70 years and in those with depressed left ventricular function and functional regurgitation.

The EVEREST II trial is debatable, both in terms of trial design and of results interpretation. The safety advantage of the MitraClip is mostly driven by the higher rate of transfusions in the surgical arm. Unfortunately, the small number of patients with functional MR and the exclusive enrollment of surgical candidates do not reflect the real-world patients undergoing the procedure. Currently, 2 post-market registries are ongoing: the ACCESS-EU in Europe,

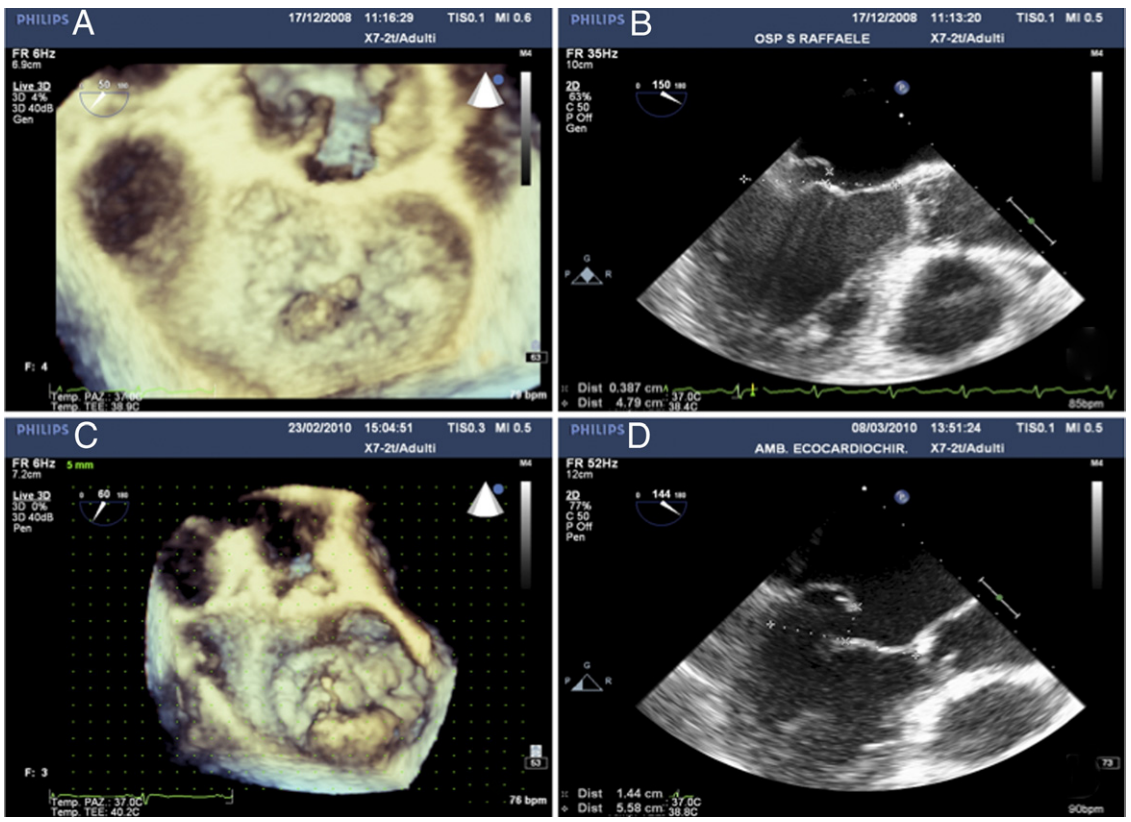


**Figure 5** **Example of an Ideal and a Suboptimal Anatomy for the MitraClip**

**A and B** are are 2 images from an ideal candidate for the MitraClip procedure. The extension of the prolapsing segment is limited **(A)**, and the flail gap is <5 mm **(B)**. **C and D** are 2 images from a suboptimal candidate (degenerative mitral regurgitation). The 3-dimensional (3D) surgical view shows a wide prolapsing segment **(C)**, whereas the 2-dimensional (2D) left ventricular outflow tract view shows a long flail gap **(D)**.

and the REALISM (Real World ExpAnded MuLtIcenter Study of the MitraClip System) in the United States. The initial data suggest that patients undergoing the MitraClip procedure in the real world are older, with more comorbidities, with more depressed left ventricular function, and mostly with functional MR. Hospital mortality remains low (below 2% in the ACCESS-EU, despite the average logistic Euroscore at approximately 20%), and early efficacy is improved (procedural success rate >90%). Improvement of quality of life and New York Heart Association functional class as well as reduction of MR grade have been reported (32), but published data are not yet available.

## Patient Selection: Surgery or Percutaneous Interventions?

Selection of the surgical versus percutaneous approach is challenging, in the absence of evidence. In our experience, the decision is undertaken by a heart team and individualized on the basis of clinical and anatomical factors, keeping the surgical option as first choice. High-risk patients are considered for the procedure, but only a subgroup of patients can be treated by the MitraClip procedure, according to the anatomical criteria (Table 1) derived from the EVEREST inclusion protocol. We routinely use 3D TEE (Fig. 5) for patient screening, because it increases accuracy and delivers a more objective assessment of the target lesions (33). In the future, the combination of the MitraClip with an annuloplasty device could expand indications and improve efficacy and durability. Some patients treated with anatomical characteristics beyond the EVEREST criteria show reasonable short- and mid-term results (34,35). However, treating patients with more complex anatomy could be associated with procedural failure and shorter durability and should be performed only by expert operators with sufficient experience.

In younger patients with degenerative MR without comorbidities, surgery can be carried out with minimal risk and with long-lasting results (36). The Mitraclip procedure should be considered in elderly subjects or those with comorbidities. The ideal degenerative MR candidate has a prolapse or flail lesion limited to 1 segment (Figs. 5A and 5B). The width of the prolapsing segment should be <1.5 cm: larger flails are at risk of stenosis and require multiple clips. Technical feasibility is also influenced by the flail gap, a measure of the distance of the free edge of the prolapsing segment from the facing leaflet (Figs. 5C and 5D).

For functional MR, the MitraClip is emerging as a valuable alternative, because surgical risk is usually high (37), although the EVEREST data are missing in this field. Compared with outcomes of degenerative patients (38), survival benefit after surgery has not yet been demonstrated (39), and the repair is less durable (40). Therefore, in presence of favorable anatomical characteristics, we consider the MitraClip as first-choice treatment, unless the patient is a low-risk surgical candidate. However, there is a strong need for dedicated studies in this field to clarify the clinical role of the percutaneous treatment of functional MR versus medical and surgical therapy or other heart failure therapies.

## Conclusions

We have witnessed the evolution of a surgical procedure into a percutaneous technique. This process is introducing new challenges and opportunities. Minimization of invasiveness and intraprocedural online assessment of repair result are the main advantages, compared with surgery. The main challenge remains the selection of patients to be treated with these new techniques, in the absence of strong evidence and with still-limited clinical and technical experience. It is mandatory that the challenges are overcome by a true teamwork effort, to enable a safe and effective introduction of the percutaneous technologies in clinical practice.

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**Key Words:** Alfieri repair ■ double orifice ■ edge-to-edge ■ mitraclip ■ mitral regurgitation ■ mitral valve repair ■ percutaneous treatment ■ surgery.